MARICOPA ASSOCIATION of GOVERNMENTS

MAG Regional Concept of Transportation Operations

Technical Memorandum No. 2

- Best Practices in Transportation System Operations

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1. INTRODUCTION

This technical memorandum identifies and summarizes best practices in transportation operations and recommends applicable practices that may be adopted by the Maricopa Association of Governments (MAG) Region in the following areas:

- Freeway-arterial management;
- Traffic incident management including emergency management;
- Transit system management (including bus and light rail); and
- Multi-modal travel information systems.

This is not a comprehensive listing of best operational practices. Rather, this summary focuses on needs and issues that have been identified through the inventory phase of this project.

2. FREEWAY – ARTERIAL MANAGEMENT

Project stakeholders have identified several aspects of coordinated freeway-arterial management as important for integrated operations in the MAG Region. Key topics include:

- Exchange of real-time incident information between emergency responders, the Arizona Department of Transportation (ADOT), and arterial management agencies (the cities);
- Exchange of real-time traffic condition information between ADOT and arterial management agencies (the cities);
- Coordination of freeway and arterial operations, particularly during incidents; and
- Shared operation of devices among regional partners.

Overall, the regional intelligent transportation system (ITS) stakeholders are concerned with managing the freeway and arterial systems in a coordinated manner.

2.1 Overview of Experience in Coordinated Freeway-Arterial Management

There are only a handful of locations where cross-jurisdictional freeway/arterial coordination has been implemented. There are several reasons why this is a relatively rare approach. First, many locations are still struggling to implement ITS systems and devices to meet their primary (individual) agency functions. Second, unlike in the Phoenix metropolitan area, there is little available capacity on most cities' arterial networks. In many locations, the key capacity constraint to diverting traffic from a freeway to an arterial is the need to route traffic into a single left-turn or right-turn lane when diverting to or from the freeway.

Lastly, cross-jurisdictional freeway/arterial coordination is relatively rare because in some cities, the principal arterials that do have available capacity are controlled by the state that also controls the freeway system. Because of this, there are no interjurisdictional operational issues to coordinate.

Despite these constraints, there are some approaches and successes in freeway-arterial coordination that might be useful in the Phoenix area. The following discussion provides some insight on how agencies are working together to respond to regional operational needs, particularly in response to incidents.

Miami, Florida. Miami-Dade County Public Works is responsible for operating all traffic signals throughout the entire county. They staff an operations center on a 24-hour, 7 days per week basis (24 x 7), with the primary off-hours staff role being monitoring of outages and dispatching maintenance if there is an outage. During normal working hours, in addition to problem tracking and response, engineers work to maintain and manage the system, and to improve signal progression.

Florida DOT and Miami-Dade County have agreed that the DOT should telephone the County operations center to inform them of major incidents that may affect arterial operations. Operators will then check to ensure that the affected signals are operating properly. If traffic engineers are present at the County operations center (during normal working hours), they may choose to implement a special timing plan. Miami-Dade County will not implement special signal timing plans in response to incident-generated traffic unless a traffic engineer is present.

Portland, Oregon. The City of Portland and the Oregon Department of Transportation (ODOT) are implementing a new system on Barbur Boulevard, a major arterial that runs parallel to I-5 for several miles in the south end of the City. Barbur Boulevard is a natural diversion route for I-5 when incidents occur. This project will install additional detection, closed-circuit television (CCTV), dynamic message signs (DMS), and changeable message signs (CMS) on Barbur Boulevard and provide resources for new signal timing plans to be developed to improve Barbur Boulevard operations when there are incidents on I-5.

If an incident occurs on I-5, the City of Portland will confirm the incident location and impact, and can elect to implement a diversion plan on Barbur Boulevard. To support the diversion plan, the City or ODOT will post messages on arterial DMS (supported by messages on I-5 DMS operated by ODOT) and alter signal timing to manage the diversion route. The system will allow the City to create diversion routes on various segments of Barbur Boulevard, directing drivers off and on I-5 around an incident in the shortest amount of time. If an incident occurs after hours when the Traffic Operations Center (TOC) is staffed, ODOT TOC operators will have access to the City of Portland’s integrated signal system platform to make changes to the signal timing plans and DMS messages when the City is unable to staff the operations center. The Barbur Boulevard project is in the early stages of development. ODOT and the City are working on the details of the Concept of Operations specifically for this project.

Minneapolis, Minnesota. The Minnesota Department of Transportation (Mn/DOT) and the City of St. Paul implemented a system to manage arterial traffic during freeway incidents. The project included:

- CMS on freeways to advise of suggested diversions;
- Fiber-optic blank-out trailblazer signs (an arrow with three heads; any single head can be illuminated) on arterials;
- CCTV on arterials to monitor flow; and
- A SCATS-brand traffic-adaptive signal system on arterials, and associated additional detection.

This project’s operational goal was to improve operations on the arterial network during freeway incidents. It was thought that by adding detour signing (trailblazers), drivers could be directed to the routes that would best respond to additional demand. Several alternate routes were identified and instrumented. The City and State agreed that the system would be activated only when incidents occurred that blocked two of the three freeway lanes and were predicted to last at least 30 minutes. The City of St. Paul had control of the trailblazer signs. Because they did not provide staff 24 hours a day, control was passed to Mn/DOT. After testing the system over several years, Mn/DOT has made the following assessments:

- Drivers do not respond to trailblazers, but drive where they individually believe they can find the shortest path. Mn/DOT will not install trailblazers for this purpose in the future;
- Capacity constraints (especially single left- or right-turn lanes) restrict the traffic volume that can be diverted from the freeway;
- CMS on arterials that advise drivers of major incidents as they approach the freeway would be highly beneficial; and
- SCATS, or any adaptive signal control software, is the best means to maximize throughput on arterials that are often used as diversion routes during incidents.

2.1.1 Coordination of "State" Signals and Local Jurisdiction's Signals

Another aspect of freeway-arterial coordination is the coordination of traffic signals at freeway interchanges (which are often owned and operated by the State DOT), with adjacent signals on the arterials. Just like any other traffic signals owned and operated by different jurisdictions, there are a variety of approaches to coordinating operations.

The simplest means, at least technically, is for one agency to turn over operations to another. In Oregon and Washington, the state typically agrees to turn over interchange signals to the local jurisdiction, if the local jurisdiction so requests it. They also are allowing the locals to implement their own hardware (e.g., NEMA vs. 170 controllers), as they see fit. The interagency agreements cover basic maintenance and operational parameters, and cost implications. The reverse arrangement also is very common, with the State taking over operations and maintenance of signals on arterials that intersect with freeways. This is more common in smaller jurisdictions that would likely contract with another agency for signal maintenance.

Another option is available if the arterial is in time-based coordination. Some agencies have agreed to send a synchronization pulse from one local master to another (or to a single controller), and to input the same time-of-day timing plans in each system. This is common among agencies in Washington State.

A third option has been implemented in only a few locations across the United States. This option helps to manage queues. The two agencies must agree on what would be an excessive queue. Loops are placed to detect the queue, and the signals are set to extend green times to clear the queues. The efficacy of this solution depends on local conditions, as it would be like implementing a pre-emption at a fairly frequent interval, and coordination (if it exists) would be compromised; therefore, this solution is best for small groups of signals. In addition, the loops and amplifiers must be regularly maintained to ensure this approach works.

The key to any operation is excellent interagency communications and shared operational goals.

2.2 Exchange of Real-Time Incident Information

All transportation agencies would like to have timely information on incidents that may affect their operations. In particular, cities in the Phoenix metropolitan area would like to receive timely information on freeway incidents that may cause diversion to the surface streets that they manage. Utilizing existing infrastructure and traffic management tools, local agencies could be better prepared to use this information to respond to unusual traffic volumes generated by incidents, by adjusting signal timing plans, posting messages on CMS, or through other means.

The first step in determining what information is useful to which agencies is to establish an operational concept for regional transportation operations. In the inventory phase of this project, stakeholders identified needs related to freeway incident detours and diversion plans. This information is one piece in planning for an overall incident response operational concept that integrates freeway and arterial network management. This operational concept will identify the purpose and outcomes desired, which will then help determine the proper technical and institutional approach. This project will address the Region's operational concept.

There are four key aspects of real-time incident information exchange:

- Understanding how each agency might use incident data – this helps define the type of incidents that will be reported, the frequency, and the means of response;
- Extracting the data from the most appropriate source;
- Communicating the information (by phone, electronically, etc.); and
- Implementing the appropriate response.

The following sections describe some effective approaches in place across the United States.

2.2.1 Effective Practices

Like coordinated freeway-arterial operations, sharing incident data across jurisdictions is relatively uncommon; therefore, there are several leading edge practices but their effectiveness has not been well established. The following sections provide insight into how agencies are working together to respond to regional operational needs, particularly in response to incidents.

2.2.2 Leading Edge Practices

The most common means for transportation agencies to detect incidents on their own facilities is based on information from emergency response agencies – either via by hearing of incidents by monitoring police scanners, being informed by their service patrol staff, or being called by enforcement. A minority of incidents are detected using CCTV and detection, although some are. Transportation agencies have not instrumented all of their facilities, and they are not able to observe camera images full-time. Thus, they are not aware of all incidents on their systems.

The most effective means of providing incident data to any agency is by extracting the data from an emergency responder's (typically police) computer aided dispatch (CAD) system, and importing it to an appropriate interface at the interested agency. Many state DOTs have done this: the Washington State Patrol (WSP) has allowed the Washington State DOT to monitor CAD information by providing them with a remote WSP CAD terminal at the Traffic Management Center (TMC). The DOT filters the information at their workstation, to ensure that only accident information is shown on the terminal. This arrangement reflects a high level of trust between the two partners. The California Highway Patrol sends filtered CAD data to a web site that is available to the public at large, and can be monitored by Caltrans TMC staff.

No locations were found where data is sent from a local (city or county) police dispatch to a freeway management system; however, in the Cincinnati region, many of the local counties operate consolidated 911/CAD dispatch centers for all agencies within the county boundaries. The current ITS Plan for greater Cincinnati calls for providing filtered CAD data to the regional freeway management system, known as ARTIMIS. The ARTIMIS system currently posts freeway incidents, and will add incidents on major arterials in the future. ARTIMIS workstations are already located at the two local transit agencies, and will soon be placed at local cities and counties that request them. These agencies will be kept up-to-date on regional incidents by viewing information on the ARTIMIS workstation.

Because Arizona Department of Public Safety (DPS) does not have CAD, communicating freeway incident information to other agencies is done manually via phone.

Recently, Rural Metro has agreed to allow the City of Scottsdale traffic engineering department to place a CAD terminal in their TOC. This agreement is early in the making, and not yet implemented; however, they may serve as a model for the region.

Another effective means of sharing incident information is to co-locate dispatch with traffic operations centers. San Antonio, Texas, Miami, Florida, and Detroit, Michigan are examples of locations where the State DOT TMC is collocated with the State Police agency dispatch. Although there are no electronic connections between the agencies in these centers, working side-by-side allows staff to verbally share information. In addition, the images on the DOT's video wall are available to all in the center.

2.3 Shared and Joint Device Control

In many of the examples of effective practices noted above, the agencies have agreed to provide each other with access to their field devices under specific circumstances. There are several means of providing multi-agency access to devices:

- Providing the device software (and, if required, the phone number to the device modems) to the partner operating agency. Many agencies operate dial-up devices, the most common of which are CMS and traffic signals. Based on pre-developed operating agreements that outline specific criteria for one agency to access another's devices, the device software and telephone numbers to the devices are supplied to that partner agency. This approach is followed in Portland, Oregon.
- Implementing a workstation and software in a partner agency's TMC. Some agencies, such as the Virginia DOT, provide a remote workstation for partner agencies to access devices using their central software. This is the case in the Seattle area with the WSP sharing control via a remote workstation to the WSDOT freeway management system (as noted above).
- Using software specifically designed for shared control of devices. The freeway management system software developed originally for the Georgia DOT is now in place in Georgia, Salt Lake City, Utah, Portland, Oregon, and in Florida in the Turnpike District. In addition to basic freeway management functions, the software allows multiple agencies to access each other's field devices. The "owning" agency has ultimate control over their own devices and can lock out certain users or take control away from a user (similar to a network administrator's capabilities). Only the Georgia and Oregon DOTs have developed agreements with their partners on the joint use of devices via the Navigator software.

Section 3.3.1, Institutional Issues, provides more insight on joint operations.

2.4 Ramp Meter Operations

There are two basic approaches to ramp meter operations: local and coordinated operation.

- Local Operation – This is the most common type of ramp meter control in the United States. The ramp meter can operate under time-of-day plans, traffic responsive rules, or traffic responsive "bounded" by time-of-day rules. These approaches work well for systems with relatively long spacing between ramps and moderately high congestion levels. In highly congested corridors or in locations where ramps are closely spaced, coordinated operation among ramps in the same corridor or geographic area is needed in order to better distribute impacts and to better address the level of congestion encountered.
- Coordinated Operation – Central software controls all ramp meters on a corridor. For highly congested corridors, this method has proven to increase mainline volumes and reduce turbulence in the traffic stream. Seattle, Washington and Minneapolis, Minnesota are two locations with a long history of operating centrally coordinated ramp meters. Portland, Oregon is in the early stages of implementing the SWARM algorithm, developed by Caltrans (but not yet implemented in California) for central ramp meter control.

The treatment of ramp queues also can be accomplished in several ways. For this project, the approach to ramp queues will depend on operational needs and goals, and on policy. The most common means of managing ramp queues is through end-of-queue detection, where a loop is placed upstream of the ramp meter. There are two common approaches to modifying metering rates based on queue lengths. The first approach is to place detectors where an agency determines that a queue at this distance from the meter would be considered a problem. The loops are often referred to as queue detectors. The meter rate is increased if a queue is detected at the queue detector for a given length of time. In some systems, the meter rate is increased more if the queue remains at the queue detector for a specified longer time period.

The second approach is to place a detector at the location considered to be the maximum tolerable queue. If traffic queues are detected on the loop, the ramp meter rate is increased to the highest tolerable rate to reduce the queue. This system was installed in Phoenix metropolitan area.

For locations where queuing is a consistent problem, the two approaches may be combined to prevent queues from reaching the maximum tolerable length. Combining the approaches allows agencies to manage queue lengths gradually, unless the queues grow too quickly to be easily controlled in which case more dramatic action can be taken. This approach tends to manage developing queues before they get critical and still provides protection against intolerable queues. The Seattle region is the only location known to implement this combined approach. Florida will implement this design in the Miami region.

The Seattle area has incorporated ramp queues in its fuzzy logic, coordinated metering algorithm. Mainline conditions and ramp queues are taken into account in the real-time calculation of metering rates. This allows the system to trade-off queues and mainline conditions explicitly in the control algorithm instead of over-riding the metering rate calculated based on mainline conditions when queue conditions develop on the ramp.

It also should be noted that queue detection may be located on adjacent arterial streets, if it is acceptable to store cars in lanes on arterials (e.g., a right-turn only lane that approaches the ramp). This approach also has been applied in Seattle.

2.5 Institutional Agreements

The MAG transportation operations stakeholders' interest in joint arterial/freeway management suggests that the affected agencies must concur on operations concepts, protocols, and potentially any future capital or maintenance cost sharing. There are various types of agreements and/or memoranda of understanding (MOU) that may be needed.

Three types of functions may require agreements or MOUs:

- Joint operation of devices;
- Sharing data; and
- Transfer of funds or other resources.

Whether a formal agreement or an MOU is required depends on:

- Historical relationships among agencies;
- The level of risk being taken on by each agency;
- The impact of the agreement on any of the partners to operate as they require;
- The need to transfer funds between agencies; and
- Agency policy.

With regard to data sharing and joint operations, if agreements or MOUs are not explicitly required, agencies could consider continuing to operate without them. Across the United States, there are few examples where agreements or MOUs are in place, even though agencies operate jointly or share devices. For example Georgia DOT does not have operating agreements in place with their local partners. Some successful joint operations rely on good faith, rather than written agreements that may be an attempt to force one partner to perform. Agreements are often very difficult to enforce and sometimes provide little leverage. In addition, formal written agreements of any type may be difficult to enact because most agencies' legal counsels have been unable to create language that is satisfactory to all parties to an agreement. In the District of Columbia, agreements on data sharing are now more than four years in the making, and are hung up in legal process.

This is not to say that developing and documenting joint goals, understandings, conditions, protocols, and restrictions is not useful. On the contrary, it is very useful to write down these things to ensure mutual understanding and to train staff. Most agencies that do operate well jointly use written, but informal, methods and procedures to ensure mutual understanding and agreement between partner agencies in ITS operations. On the other hand, the very process of establishing a regional agreement on how to operate the regional transportation system and memorializing it somehow (in an MOU or other means) will require the endorsement of elected officials, and may provide access to needed resources to implement the systems and infrastructure required for joint operations.

2.5.1 Determining if a Written Agreement or MOU is Required

In terms of the three functional areas noted above (operations, data sharing, and funding), there is only one instance where agreements are required by law. The transfer of funds between agencies always requires some form of written agreements to document the transfer; however, not all operations or data sharing require agreements. To assist in determining which situations would benefit from agreements, agencies should ask themselves the following questions:

Joint Operations

- Does operating together introduce significant new or additional risk to public safety that was not present when the agencies did not operate jointly? Are there mechanisms in place that mitigate that risk to a minimum level?

  For example, consider the ability to post messages on a neighbor's CMS. Should only certain messages be available to certain partners?

- If one agency chooses to unilaterally remove itself from jointly operating with another agency or agencies, would the risk to public safety be significantly negatively affected?

  For example, consider the consequences if one agency no longer participates in coordinating CMS messages.

Joint Operations and/or Data Sharing

- Does operating together or sharing data introduce significant new or increased threats to public privacy?

  Consider the use of video images and filtered CAD data. Can private information be removed completely from these?

2.5.2 Managing and Tracking the Interlocal Agreements

Over time, ADOT has developed several different Intergovernmental Agreements with local cities. These agreements cover a wide variety of roles and responsibilities at signals at freeway interchanges. Currently the method used for managing the agreements is placing the paper agreement in the signal files. Managing the resulting paper trail of interlocal agreements has not been an issue for other agencies because they typically take a standard approach, or have very few agreements to manage. This is not the case in the Phoenix metropolitan area. An approach could be that some agreements be combined and redrafted. To keep better track of the agreements, in addition to a paper file, it is suggested that the documents be scanned and attached to a database connected with the central control system for the traffic signals, or placed in a stand-alone signal inventory database.

2.6 Arterial Management

The arterial network in the Phoenix metropolitan area is somewhat unique in the United States. There are a significant number of major six to eight-lane, high-speed arterials in a one-mile grid configuration, operating with signal control at major intersections. These arterials can provide additional network capacity to relieve freeway congestion during incidents.

2.6.1 Advanced Signal Timing Approaches

The more advanced signal timing approaches are: traffic responsive and traffic adaptive.

- Traffic Responsive – Traffic responsive technologies change signal timing plans based on traffic volume thresholds (rather than time of day). They are considered a best practice for locations where traffic volume patterns are difficult to predict from day to day, and where traffic conditions are generally moderate to heavy, and the highest level of operational efficiency is required. Operating traffic responsive systems requires a high level of detector maintenance, because volumes and/or occupancies must be accurate to ensure that proper timing plans are implemented.

- Over 50 percent of the jurisdictions that are members of ITE and responded to an August 2000 national survey (conducted by the Federal Highway Administration [FHWA] Office of Travel Management) indicated that they operate traffic responsive signals or signal systems.

- Traffic Adaptive – Traffic adaptive signal control makes real-time adjustments to traffic signal timing based on current conditions. This differs from traffic responsive strategies in that new signal plans could be generated for every cycle; therefore, an endless number of timing plans can be produced. They are most beneficial in areas with very extensive fluctuations in traffic demand or in areas that experience consistent growth of traffic over time. Traffic adaptive systems do not require timing plans to be updated periodically by agency staff. Domestically, these strategies are not in widespread use and are still considered somewhat experimental. These systems are quite complex, require additional field detection and surveillance to ensure proper operation, and also require staff training before implementation.

  The reasons for this deployment lag include cost issues related to additional field equipment (detection, cabinet equipment, etc.) and concerns that algorithms for adaptive traffic control simply do not perform well. In particular, when traffic volumes are heavy, the state-of-the-art algorithms do not perform better than an up to date timing plan. Also, system complexity drives the need for additional training.

  As the initial obstacles to implementation are overcome, these systems have the potential for substantial benefits. Some traffic-adaptive systems currently implemented in the United States include:

  - RT-TRACS. This system combines several algorithms – OPAC, RHODES, and RTACL – and has been implemented on arterials in Tucson, and Tempe, Arizona; Chicago, Illinois and Reston, Virginia. The system was developed by FHWA specifically for arterial management.
  - Sydney Coordinated Adaptive Traffic System (SCATS™) is a computer based area traffic signal control system. It is a complete system of hardware, software, and control philosophy. It operates in real time, adjusting signal timings throughout the system in response to variations in traffic demands and system capacity. The SCATS system has been deployed in Oakland County, Michigan; St. Paul, and Hennepin County, Minnesota, and Durham, North Carolina. The system can manage arterial grid networks and arterial progression. As noted previously, the system in St. Paul has been found effective for managing arterial traffic surges due to freeway incidents.
  - United Kingdom's Split, Cycle, Offset Optimization Technique (SCOOT) The SCOOT system has been deployed in Toronto, Canada; Arlington, Virginia; and Anaheim, California. Like SCATS, the system can manage grid networks or arterial progression.
  - The Automated Traffic Surveillance and Control System (ATSAC) – ATSAC is a system developed expressly for the City of Los Angeles, California. It is principally a traffic responsive system, with traffic adaptive capability, and

provides centralized control for the City's complete traffic signal network. The system detects when timing plans are aging and provides an on-line timing plan generation program. The plan still needs to be reviewed, adjusted, and implemented by staff.

- The system has extensive on-street detection that is being used to provide a first-of-its-kind traffic information web site with arterial travel times (http://trafficinfo.lacity.org), on a par with freeway travel time information systems. The site receives between 100 and 200 hits per day, with the number reaching near 1000 on special event days such as for the Democratic National Convention. The City believes they would get more day-to-day traffic if they invested in a marketing strategy. They have never marketed the site.

The cities implementing traffic adaptive control are using it at selected locations, and using more conventional control strategies elsewhere.

2.6.1.1 Effective Practices

The most effective practice is to implement the appropriate signal timing strategy for conditions given budgetary constraints. The consulting firm PB Farradyne recently interviewed a dozen leading traffic operations/traffic signal engineers from across the United States. Their advice is to ensure that you are getting the highest level of performance out of your existing system before trying something new. They note that the implementation of traffic responsive control strategies does not alleviate the time that must be invested in calculating, implementing and maintaining signal timing. And traffic adaptive strategies require additional training and, due to additional detection, more field maintenance, although they do reduce the time devoted to traffic signal timing plan generation and input.

Given these considerations and assuming there are adequate resources, making a decision to implement a new signal timing strategy should be supported based on cost-benefit and operations modeling. Advanced micro-scale simulation models such as PARAMICS or VISSIM allow users to input and apply the actual control algorithms they plan to implement. These types of models should be used when evaluating traffic adaptive control.

2.6.2 Operations at Jurisdictional Boundaries

In the Phoenix area, the local agencies have been actively turning over operations to adjoining agencies when this will improve a corridor's operations. This has led to difficulties in keeping track of inter-agency agreements. The following section addresses these issues.

2.6.2.1 Effective Practices

The most common and effective means of coordinating operations at jurisdictional boundaries is to turn over operations to a single agency. Indeed, Miami-Dade County is an extreme example of this approach where the County operates every jurisdiction's signals throughout the County. The same arrangement exists in Clark County, Nevada and in Tucson, Arizona. This example is followed to some extent in other locations throughout the United States. Typically, larger agencies were asked to operate and maintain a smaller agency's first signals, and the practice simply grew. In the west, this is a less common approach; however, agreements on integrated arterial operations are very common. In Los Angeles County, several cities are agreeing to implement the same software package for central signal control and to replace controllers, all with the goal of easing interjurisdictional operations. They also will turn over control of some major arterials to the County.

Over time ADOT has developed several different Intergovernmental Agreements with local cities. That led to a proliferation of responsibilities and roles at the traffic interchange signals. It is suggested that the lead agency, redraft and consolidate all agreements. To keep better track of the agreements, in addition to a paper file it is suggested that the documents be scanned and attached to a database connected with the central control system for the traffic signals, or placed in a stand-alone signal inventory database.

2.6.3 Emergency Vehicle Pre-emption System Inter-Jurisdictional Coordination

In the MAG region, there are inconsistencies in how Emergency Vehicle Pre-Emption systems are operated and managed across jurisdictions. The most significant issue is that emergency response agencies cannot pre-empt signals in every jurisdiction in the Phoenix metropolitan area. Once again, although not entirely unique, the magnitude of the issue is unique because so many agencies are involved and a wide variety of approaches are applied. The policy direction being developed in this project, which suggests that a standard approach should be agreed on and applied, is an effective practice, and is commonly followed across the United States. A common practice is for agencies to agree (usually informally) to a standard approach to pre-emption operations. It is typical for the traffic engineers to simply agree on what that operation will be. This way, emergency responders can expect the same operation across jurisdictions.

When determining whether each vehicle should be recorded when pre-emption occurs, the most effective practice (which also is very common in the United States) is to record every pre-emption for every vehicle. This helps protect all parties if any mishaps or system abuses occur.

2.6.4 Operating Hours and Procedures

The Phoenix area was concerned about operating hours for traffic signal operations staff. Much of the interest centered on off-hours operations, but also covered normal working hours.

Most cities with signal systems of about 175 to 200 signals or less do not manage the signal system daily via the central control system (if they operate a central control system). The central control system exists to better manage the signals and reduce staff time in the field. Very few agencies of this size actually monitor operations during peak periods. In larger systems (over 200 signals) it is more common to actively monitor operations, and it is more common for these agencies to implement CCTV and DMS and to have direct and continuous communications to these devices to support real-time operations (as opposed to dial-up operations). The critical differentiator between these approaches is not actually the number of traffic signals in the system, although there is a correlation, but rather the benefit that can be derived from staffing the system in a more directed fashion. The correlation between number of staff and system size is strongly related to benefits, the availability of funding for staff, and to the presence of equipment to manage the system centrally in a real-time fashion.

Signal system operations contrast with the mission and operations of most centrally controlled freeway operations systems. For most freeway management systems, the primary mission is incident management. Because incidents occur in a random way, and many high-impact incidents occur in off-peak hours, systems must be staffed and actively managed 24 x 7.

A few very large cities and counties, such as Los Angeles, Miami, and Chicago, staff their signal operations centers 24 x 7. The benefit of ensuring a timely response to outages and problems even in off-hours in these highly congested cities justifies the staffing cost.

To determine what operating hours are most effective, the desired functions of a TMC, supporting operations and likely benefits should be estimated. This approach should help determine whether staff should be assigned to particular periods, if at all.

Another staffing option for cities and counties is to allow the State DOT (or another 24 x 7 agency) to have off-hours operating control over the city's or county's systems. Many locations across the United States including Portland, Oregon; Los Angeles County, California; and Palm Beach County, Florida are doing this. Each agency must agree on what types of actions are allowed, and what software will be implemented to limit the possible actions a partner agency could take. As described earlier, an operational concept should be developed as a first step and the operating parameters and protocols need to be defined. This approach also may be carried out between adjacent cities. Pooling of available staffing resources may permit extended operations that may not be possible otherwise.

Several State DOT's contract out for TMC staff including Michigan, Virginia, and Florida. Some contract only for operators while others essentially privatize operations and contract out supervisors and operators.

3. TRAFFIC INCIDENT MANAGEMENT

Incident management covers a broad range of operational issues. The MAG region has been proactively implementing improved incident management practices over the past five years with many great successes. Arizona is a leader in Traffic Incident Management programs and has one of the most comprehensive statewide incident management strategic plans in the nation. Lack of funding is the primary reason that progress has been slowed. A large number of improvements have been accomplished by making operational changes within agencies.

Incident management can be described in five steps:

- Detection;
- Verification;
- Response;
- Management; and
- Clearance.

Incident management also includes traveler information services. This section focuses on areas that the MAG ITS stakeholders felt would benefit from change.

3.1 Alternative Route Planning

ADOT has completed a statewide alternate route plan. This plan is used on a near daily basis by ADOT personnel to reroute traffic during major incidents. A Maricopa County alternate route plan was completed in the early 1990's and needs to be updated. A current ADOT project is underway to develop a software package to assist with implementation of alternate routes and should be deployed by 2003. Currently, ADOT's alternative route plans address routing only onto other State-owned and managed routes. Planning has not been done to address alternative routing on other agency's arterials. Across the United States, it is uncommon for agency's to develop formal alternative routing plans that divert traffic onto another agency's arterials. There are many reasons for this. Most agencies are unable to come to agreement on such plans, or the local arterials are geometrically or structurally inadequate to handle the truck traffic that would divert, or, there is no means to direct traffic back onto the freeway once they have been diverted onto arterials.

Establishing alternate routes takes substantial resources and may affect multiple jurisdictions; there are many signs needed, personnel are often required to manage traffic, and most arterials cannot handle a great deal of traffic diverted from a freeway. As traffic must turn right or left on exiting the freeway to access arterials, and this is typically a capacity choke point at signals, large additional volumes cannot be accommodated on arterials from freeway diversions. Implementing signal coordination that could respond more effectively to incidents that divert traffic from freeways to arterials is addressed in Section 2. The best method for managing traffic during freeway incidents is to inform drivers on arterials before they choose to use the freeway.

In the Phoenix metropolitan area, conditions are no different. Diverting traffic around a freeway incident by moving traffic off the freeway onto adjacent arterials is constrained because of the requirement for left or right turns once on the arterial to return to the freeway, or to reduce traffic to a single lane before merging onto an arterial; however, the Phoenix metropolitan area does have an excellent grid arterial system that operates at higher speeds and has a greater capacity than any other similar-sized city. The only means to take advantage of this system for incident diversion is to inform drivers well in advance of the freeway incident – likely even before the driver has determined that they will enter the freeway – so they may use an arterial route for their trip (or a portion of the trip) rather than a freeway route that would lead them to congestion. During off-peaks in particular, the arterial system can accommodate additional traffic volumes.

The alternative route efforts in the region rank favorably with national efforts. ADOT's statewide DMS system should be used whenever possible to give motorists substantial advanced warning of alternate routes. The excellent work done by collective agencies such as Phoenix and ADOT on freeway incident management coordination and for special events can and should be used as a model for multiple agency deployment for major alternate route implementation.

3.1.1 Institutional Arrangements

Police, fire, and transportation agencies in the MAG Region manage major events well. In October 2001, the World Series, State Fair, NASCAR race, and Arizona State University football game drew over 600,000 spectators to the area on a single day. The coordination and cooperation of all the agencies involved resulted in all events being handled as effectively as possible. Traffic management required a large effort by all agencies, who demonstrated the ability to work together on a large scale.

Phoenix Fire is a national example of shared resources. They provide CAD feeds to other agencies (including ADOT) and operate a communications system for several fire departments. DPS and the Phoenix Fire Department share a helicopter that makes medical and police flights.

ALERT and the member agencies of the West Valley pilot project REACT are working together on an informal basis to assist with major incident closures and provide traffic control at major traffic incidents that affect more than the freeways. The emergency responders train together, provide assistance when requested to respond to incidents, and jointly plan for and staff major events such as those held at the Phoenix International Raceway.

MAG has provided support for the freeway service patrol program operated by DPS. This program provides vehicles and operators to handle assists and support DPS officers in handling incidents.

Emergency response agencies in the Phoenix area have a good working relationship; however, there are more opportunities for formal interagency agreements, multiple agency training, and establishing performance standards to improve the overall handling of incidents on the entire roadway system. Specifically, the agencies should be working to formalize open roads policies, to share investigative resources for traffic incidents, and to work more closely with transportation operations staff at the state, county and local level.

3.1.2 Hardware/Systems

Agencies in the MAG Region have traditionally developed their own systems and have not shared real-time data until recently. One big drawback to a good interagency data system is the lack of a CAD system at DPS. Other areas of the nation are sharing real-time data between police and transportation authorities, and video output from DOT CCTV systems is shared with police, fire, and (in a few locations) towing.

A new statewide CAD system for DPS has been funded. Until it is implemented in mid to late 2003, operators with many other duties will continue to be relied upon to make phone calls to pass on information to other agencies that provide support through response of traffic control personnel and motorist notification by DMS. When the CAD system is operational, data sharing can occur that will streamline the management process for several agencies.

The hardware system ADOT uses to deploy DMS messages is being upgraded. It will still be operator-intensive to get messages posted, especially on several signs. San Antonio, Texas has a system that automatically posts messages as soon as an incident is verified. This process allows them to post messages minutes faster than Phoenix or most of the systems in the nation.

Though improvements are being made that will allow a greater sharing of information, existing and new systems should be enhanced as much as possible to facilitate the sharing of data between jurisdictions and agencies.

3.1.3 Getting Incident Data to Partners and the Public Quickly

During a national incident management conference in March 2002 in Irvine, California, participants were asked to provide their major concern about how incidents are managed, from a professional and personal point of view. The overwhelming personal concern was for good timely motorist information. To meet this need, all agencies involved in incident management must be able to provide timely and accurate information to each other so it can be passed on to the appropriate outlets for motorist information. Failure to do this consistently reflects on the management of the agencies involved.

3.1.4 Posting Dynamic Message Sign and Highway Advisory Radio Messages

DMS and Highway Advisory Radio (HAR) messages are critical in preventing secondary crashes and mitigating the impacts of incidents. ADOT currently has the nation's largest DMS statewide system and can provide motorist information at key decision points. For example, motorists who observe a message in Flagstaff can delay their trip or travel an alternate route to Phoenix when Interstate 17 is closed.

Posting messages quickly and accurately is a must for all types of incidents. ADOT's original message inventory had over 3,000 possible messages and was time consuming to use. A national effort is underway to standardize messages and to eliminate delays and confusing messages.

DMS should only be used for crucial information that a motorist needs to know about routes being unusually congested, closed, or impacted by construction or special events.

DMS messages on city or county-owned signs are currently delayed after hours (because there is no staff available at their operations centers) but should be posted by a 24-hour operation such as ADOT's TOC. This process would require additional agreements between agencies.

3.1.5 Incident Detection Methods

The freeway incident detection approach used in the greater Phoenix area relies on calls from emergency dispatch, and operator's scanning the CCTV images. The timeliness of incident detection by ADOT ranks favorably with other locations in the United States.

There has been some discussion regarding the use of an incident detection algorithm for freeway incident detection at ADOT. No agencies responsible for freeway management have been successful in implementing incident detection that relies solely on detector inputs. There are too many false calls, and detector maintenance is difficult.

Drivers (mostly) or passengers calling police or traffic management centers while driving on freeways using cellular telephones are now the most common method used to report incidents. Problems with this detection system include callers not knowing their locations or the incident details. With this system, each caller may only have part of the information and dispatchers have to enter information from several callers before getting a complete picture. At times, a complete picture of the incident cannot be obtained until the first responder is at the scene. Major incidents may generate dozens of calls on the same incident. These calls can actually prevent callers who are reporting on other incidents from sharing details in a timely manner. They also can lead to dispatching resources to the wrong locations. As a first step, responders and traffic operations centers assist by verifying locations with cameras and detectors when an incident is located. This information is sent immediately to response agencies for relay to responding units.

3.1.6 Data/Information Sharing

Data information sharing technology is available and being used in a few locations around the country, such as sharing CAD information as mentioned earlier; however, more information sharing could benefit agencies and the motoring public. Since September 11, 2001, a national effort has been underway for transportation and emergency services to share more information and data to mitigate the impact of terrorist attacks. Funding will be made available for improvements in this area, and agencies within the MAG Region should do preliminary planning to identify how to better share data. A current project underway is CAPWIN, an effort to tie transportation and emergency systems together in the Washington, D.C. area. This project may eventually be a model that other regions can follow.

DPS has indicated that they will share CAD data with ADOT when they are operational next year.

3.1.7 Website and 511 System (content, format, data connections including CAD)

The Highway Condition Reporting System (HCRS) in the MAG Region is now web-based and has improved capability. It is one of the few statewide systems in the nation. HCRS is essentially an internal multi-agency information sharing system, but the information input to HCRS is used to populate the public website (www.az511.com) and the 511 system.

Like in Arizona, the 511 traveler information number also has been implemented in jurisdictions such as Cincinnati, Utah, Virginia, Florida, Minnesota, and Nebraska, and allows callers to obtain real-time details on roadway conditions. This system gives motorists an easy-to-remember nationwide traveler information number. ADOT's 511 currently focuses on freeway and state highway incidents.

3.1.8 Media Connections

Traffic reporting is beneficial in the Phoenix area during peak traffic periods. Media outlets have access to the web site from ADOT, and pass on traffic information to the public through live broadcasts and their own web sites. Air support is provided by media outlets and live video of incidents can often be found on their web sites or television outlets.

Media cannot talk directly to any staff on an incident scene from any responder agencies, or the DPS dispatch center. Media must get incident information from other sources. An effective practice in Seattle, media are provided with a public information officer's phone number who is either located at the dispatch center, or will be on scene for major incidents. This link can improve incident management effectiveness, because information from and to the media is relayed faster and more accurately.

3.1.9 Roadway Marker System

Roadway markers are being upgraded in numerous states to assist in locating incidents quickly and accurately. New milepost markers are larger and contain more information, such as the direction of travel and route number. The signs are placed 1/10 or 2/10 of a mile apart and are different colors for easy recognition. When a caller notifies 911 of an incident, the call taker asks them to read the information off the roadway marker sign. This allows them to know the caller's location within a tenth of a mile.

This system is in place in several Midwest states and is being implemented in others. It should be considered for implementation in locations within the MAG Region where two roadways intersect more than once.

3.1.10 Cellular Locator System

Nationally, cellular companies were required by the FCC to put a system in place by this year that would allow cellular callers to be located within a few meters. System implementation has been delayed for a variety of reasons, and further delays are anticipated. Currently, call takers must ask for and record data fields (i.e., name address, phone number, work phone number) and incident details. Often, calls skip from one cell site to another, and calls are answered in an emergency center miles from the area where it should have been answered. Even a partial locator system, such as the one in place in Bellevue, Washington quickly allows the operator to send the call to the right response dispatch center.

3.2 On-Scene Communications

Multi-agency radio telecommunications to support for multiple agency response in the MAG region is lacking. This is a common issue across the United States. Most agencies have not implemented interoperable radio systems, as the concern in the past was to reduce cross-talk. Although some radio systems may be interoperable in the MAG region, they are often not used because it is easier to work through dispatchers than to change channels on the radio sets. On-scene communications are often face-to-face, which is sufficient unless it is a large incident requiring a large, long-term commitment. When this occurs, the ability to communicate directly is a significant benefit for quick and clear communication. Since September 11th, the trend is for all emergency response agencies to implement a means for on-scene wireless communications that works for all agencies.

3.2.1 How Responders Communicate (radios, emerging technologies, and other wireless systems)

Some radio systems are interoperable in the Phoenix area and used on a regular basis by responders. Other agencies cannot talk to each other and must go through two communications centers.

Agencies, especially supervisors, should be able to communicate directly to avoid delays and mistakes in information flow. An inventory of systems should be conducted to determine who needs to talk to each other and what has to be done to make that occur.

NexTel® is being used effectively in other cities to link key responders. Tennessee DOT response personnel are linked to other agencies by NexTel® (instead of by radio). This enables personnel to provide more details, without tying up already crowded radio channels. One drawback is the lack of availability when major events crowd the cellular system with other callers.

The local and county police agencies in Oakland County, Michigan recently joined together to implement a radio system to allow all agencies to operate on the same frequencies. The need for the system was highlighted when a shooter entered a factory that is located at the border of four cities. The four cities were unable to effectively and efficiently coordinate their actions in the field. There are several other examples of police agencies using the same radio system including Hamilton County, Ohio.

3.2.2 Multi-Agency Training

Multi-agency training is conducted occasionally; however it is often limited in number and scope. Agencies that routinely work together should conduct training at least twice per year to make sure they are able to work together effectively. The number of responders that might work together at a traffic incident is significant, and most have never attended a class with other agencies.

San Antonio, Texas provides one-day advanced incident management classes to over 200 police, fire, transportation, and towing supervisors. As a result, there has been a 40% reduction in their incident clearance time. The course was requested by the City of San Antonio Police and the Texas DOT, and was Federally funded. Phoenix should consider doing a train-the-trainer program similar to Dallas, Texas, so local experienced responders could spread the training among the local agency responders.

3.3 Incident Investigation

Traffic investigations are treated like crime scenes and long delays may occur. Unlike a homicide in a home, a traffic fatality crash scene has more elements and potential liability problems. Roadways kept closed for extended periods of time may contribute to secondary crashes, injuries to responders, delays in answering other emergencies, and long delays for motorists. Investigators need to be aware of the impacts of these closures.

3.3.1 Institutional Issues

Investigations are impacted by a variety of outside influences that can extend the period of time required to complete the work and open roadways. Police cannot return to incident scenes if they miss something, and are required to gather all evidence on the first try.

Police traffic investigators need to be taught to balance the public's needs with the needs of the investigation. When a conflict occurs in getting roads open, investigators are often reluctant to hurry in case they miss a critical fact or item of evidence.

Arizona DPS has done a good job of training their investigators and has cut over one hour off the average closure for a fatality in the past two years. This improvement can be increased through additional training and additional resources.

County and city police need to better focus on getting investigations cleared from roadways, and could benefit from cross training with DPS investigators.

3.3.2 Technologies

New technologies are currently being developed to allow complete mapping from photos entered into one software package. This technology is much improved over previous products and will be very competitive price-wise. Crash scenes will be photographed and mapped much faster than done currently.

Utah is currently a national leader in using technology to manage fatality crashes, and routinely clears roadways in less than one hour. They have discontinued the use of older technology (such as total stations) because photo measurements are much faster and more accurate. Courts in Utah are now asking for photo measurements in lieu of total stations, due to the accuracy and acceptance-level by the courts.

3.4 Overall Incident Management Performance

In a speech delivered to a national convention of emergency response professionals, George Black of the National Transportation Safety Board (NTSB) stated that the western states are better at traffic incident management than the rest of the country. Arizona is a state that has improved the delivery of incident management services at the emergency responder level and is a national leader in traffic incident management. Their ability to coordinate at incident scenes, and the emergency responder traffic management at the scene has greatly reduced traffic delays due to incidents, and made travel safer for the region. The fact that the region is working towards improving the timeliness and scope of traveler information related to incident management, and coordinating with traffic management agencies through this project is indicative of the region's leadership.

The following items describe the incident management efforts of agencies in Arizona.

3.4.1 Responder and Traffic Management Performance Measures

Performance measures have been set in a general sense, with an interagency agreement between DPS and ADOT. Other agencies should be added to this process and incident timeframes should be more actively documented.

3.4.2 How is the Region Performing Based on Current Performance Measures and Goals

DPS's efforts are documented from their incident cards, and there has been a significant improvement in the past three years in clearance times of fatalities. Other performance measures cannot be documented accurately, but this will improve with the implementation of the new CAD system. Arizona should consider using the criteria used by the WSP to document the impact of incidents on traffic. The WSP tracks when lanes are closed and opened, and tracks response and clearance times to determine their overall effectiveness. They have a performance goal of clearing lanes of all crashes within 90 minutes.

3.4.3 Quick Clearance and Reduced Liability Laws

Quick clearance and reduced liability laws allow officers to be more aggressive in getting lanes or roadways cleared of vehicles and debris. Approximately 20 states (now including Arizona) have enacted quick clearance laws. A good public information campaign is needed to make sure motorists and responders understand the law and its application.

Liability is still an issue, and legislation should be sought in Arizona to explicitly exempt responders from actions taken to clear roads (such as pushing disabled vehicles out of the traveled way rather than towing them). Currently, police in Arizona will clear the vehicles if they perceive that public safety is compromised if they do not; however, they could be subject to litigation for damages since no state law protects them. Both Illinois and California have good reduced liability laws.

3.4.4 Upgraded Clearance Procedures and Towing Regulations

Arizona still needs to update its heavy class of tows to meet current needs. The regulations, written approximately 40 years ago, need to be improved to reduce the time required to open roadways. Utah has a new recovery class of tows in the Salt Lake City area, which enables responders to clear truck wrecks much faster than before. A recovery class of tow is needed in Phoenix, Tucson, and other areas of the state.

Several states are modifying or already have modified heavy towing rules to improve clearance times.

3.4.5 Upgraded Transportation Agency Response In Accordance with the New Manual of Uniform Traffic Control Devices

The Millennium edition of the Manual of Uniform Traffic Control Devices (MUTCD) has made a change that impacts how traffic is managed for long-term incidents. Emergency responders are still exempt from meeting MUTCD standards; however, the new policy indicates that incidents will be treated the same as temporary work zones. Generally, emergency methods taken to manage or divert traffic for less than one hour can be handled by responders, using any means available. Incidents that the responders can anticipate lasting over an hour should be brought up to temporary work-zone standards with the proper cones, barrels, signs, etc. This upgrade should be undertaken as soon as reasonably possible, after an assessment of the duration is made by the first responders.

Quick response needs to be provided after hours and on weekends, to make sure that long-term incidents do not become a source for secondary crashes, injuries to responders, or potential liability problems. Policies that require a transportation supervisor to respond to the scene before additional resources can be requested may delay deployment of proper traffic control beyond a reasonable time.

Transportation agencies in the MAG Region have taken several steps to respond to and handle traffic incidents properly.

3.4.6 Updated Interagency Mutual Aid Agreements

Mutual aid agreements are common between fire departments. The MAG Region is a leader in this respect: the closest emergency response for fire or medical is sent, regardless of what agency they belong to. The combined fire dispatch center is responsible for operating this interagency procedure.

Mutual aid agreements also are in place for certain types of police task forces in the valley. More informal arrangements are in place for providing support to divert traffic from main roadways when incidents occur. Transportation agencies are working together on larger incidents and jointly conducting periodic training. Formal agreements will eventually be called for to respond to MUTCD changes.

3.5 Emergency Management

Phoenix has an excellent emergency management system, with an Emergency Operations Center (EOC) located in the city's 911 facility. All key agencies are part of the team, and the center is designed to accommodate them when major emergencies occur.

Satellite centers are used for the valley and in other cities to accommodate their needs. The overall command responsibility is tasked to the EOC.

Emergency exercises are scheduled on a regular basis and agencies provide representatives to the EOC. These exercises allow the participants to test their agencies' capabilities and the ability to work within a unified command process.

State and local agencies within the MAG Region have an excellent reputation and are national leaders in this process.

4. TRANSIT SYSTEM MANAGEMENT

Transit system management provides operations, maintenance, customer information, planning, and management functions for a transit property. It spans central dispatch and garage management systems and supports the spectrum of fixed route, flexible route, paratransit, and light rail transit (LRT) services. Transit system management collects and stores accurate ridership levels and implements corresponding fare structures. It collects operational and maintenance data from transit vehicles, manages vehicle service histories, and assigns drivers and maintenance personnel to vehicles and routes. Transit system management provides the capability for automated planning and scheduling of public transit operations. It furnishes travelers with real-time travel information, continuously updated schedules, schedule information, transfer options, and transit routes and fares.

The project stakeholders have identified two key transit system management focus areas for this technical memo: traffic signal priority systems (including bus and light rail) and transit traveler information systems.

4.1 Traffic Signal Priority Systems

Traffic signal priority (TSP) is a strategy that gives certain vehicles (namely emergency, bus, or light rail vehicles) preference at traffic signals. Priority can be pre-emptive or conditional. Pre-emptive priority is used by emergency vehicles and may be used by light rail vehicles. Under the pre-emptive mode, there is no consideration for maintaining the existing signal timing plan. Pre-emption uses a special timing plan, and if the signal is part of a coordinated system, pre-emption requires the traffic signal controller to transition out of and eventually back into the coordinated operation of the normal signal timing plan.

Conditional priority may be used for buses and light rail vehicles, and modifies the normal signal operation process to better accommodate transit vehicles. Conditional priority is considered the most effective practice.

4.1.1 Advantages and Disadvantages

The advantages of TSP include reducing transit delay and travel time, and improving transit service reliability. Transit vehicles spend an average of 15 percent of their trip time waiting at traffic signals. If the wait time could be reduced by 40 percent, a 60-minute trip would be reduced to 55 minutes. Additionally, if this route requires a five-minute headway, only 11 buses would be required to support than interval, compared with 12 to support the 60-minute trip. Europeans have deployed TSP since 1968, and their philosophy is intended to provide a high reward for transit vehicles and passengers compared to other vehicles. Zurich and Amsterdam have a majority of intersections enabled with TSP. Implementations in England and France have shown a 6 to 42 percent decrease in travel time, with a 0.3 to 2.5 percent increase in auto travel time (1).

The disadvantages of TSP include adversely impacting cross traffic, arterial progression, and pedestrians. Overall delay to all vehicles may increase in a corridor operating with TSP, particularly if the system is in pre-emptive versus conditional operation. It is typical for TSP to introduce some additional delay to general traffic. Agencies that implement TSP have made a policy determination regarding the trade-off between the added general traffic delay and transit speed and reliability improvements. Also, the costs associated with implementing TSP can be high.

TSP does not provide a high level of benefits on highly congested corridors. If corridor traffic is stop-and-go, or simply crawling along, there is little advantage to extending a green to improve transit travel time. Even if a transit vehicle gets through a signal, they are stuck on the downstream side of the signal and have made little gain.

4.1.2 Technology – Buses

Early implementations of bus priority systems have operated in one of two manners: either the priority signaling was automatic, or at the driver's discretion. Issues such as a vehicle's on-time status or occupancy were not included in the decision matrix.

One of the difficulties of some priority operations is that they actually pre-empt signal operations. This means that for signals in a coordinated system, it can take up to three cycles to return to coordinated operations. The turbulence created by the pre-emption can last for several more cycles. Thus, the impact is greater than the effect on a single cycle. Of course, if the signal is not part of a coordinated timing scheme, pre-emption would not have such an effect.

Modern traffic signal priority systems have less impact on arterial operations. Depending on the traffic signal's phase, the controller will either extend the current green phase or advance the timing of the next green phase – all while staying in coordination.

In some systems, inductive loop detectors are integrated into the priority signaling system. The transit vehicle priority response can be modified in response to traffic concerns, such as the number of cars waiting at the other approaches.

Other more recent traffic signal priority systems integrate automatic vehicle location (AVL) and CAD to determine a vehicle's on-time status. Priority requests are only sent to the signal controller if the bus is behind schedule.

4.1.3 Institutional Issues – Buses

TSP requires cooperation between transit operators and the governmental agencies in charge of traffic. These parties must agree on an operating philosophy. Key to this philosophy are policy decisions regarding transit and normal traffic operations, which may vary from arterial to arterial or neighborhood to neighborhood throughout a city.

TSP has two competing philosophies: the first is to maximize the number of people moving through an intersection. The second is to maximize the number of vehicles moving through an intersection. Most TSP installations involve a compromise between these two extremes.

A further refining of the philosophy includes consideration of whether vehicles running ahead of schedule should still be granted priority. Granting priority to shorten route travel times may ultimately allow the transit agency to reduce the number of vehicles required to provide service. This potential outcome must be weighed against the cost of seriously impacting the flow of other traffic.

4.1.4 TSP Installations and Effective Practices

Traffic signal priority systems have been installed all over North America and throughout Europe and Japan. An early implementation example is the City of Bremerton, Washington where a pre-emption-type TSP was installed several years ago. Bremerton is a community of approximately 40,000, with heavy congestion on only a few key arterials that lead to the major employment site (the Navy base and shipyard) or the ferry terminal. Transit service operates on 15 to 30-minute headways. The City of Bremerton uses Opticom™ emitters and detectors and a conditional low-priority pre-emption scheme. At the time, this was the only technology available for TSP. Because of the nature of traffic congestion and transit needs in Bremerton, this system continues to perform well. They have found that buses have saved time and had minimal impact on traffic.

After some trials the Tri County Metropolitan Transit District of Oregon (TriMet) has deployed Opticom™ emitters and detectors, and combined them with TriMet's Smart Bus concept (Global Positioning System [GPS]-based AVL). The Smart Bus knows its location and schedule status, and communicates its priority request to the signal controller only when it is behind schedule by a pre-selected threshold.

King County (KC) Metro (Seattle region) has deployed radio frequency (RF) tags for detection and uses four different strategies for granting priority, including: (1) early green, (2) extended green, (3) pre-emption, and (4) phase skipping, phase rotation, and phase re-servicing. Through a systematic process, these strategies are deployed situationally. Each strategy has a set of advantages and disadvantages. For example, the advantage of early green is that the delay saving is the amount of green time reduced from the opposing phases. The sequences of signal displays remain the same, minimum green times for opposing movements are retained, and the impact on coordination is minimal. The disadvantage of early green is that some time is taken away from opposing phases, but the impact on overall intersection operations is minimal. After implementing TSP throughout much of Seattle, King County Metro is in the process of writing Transit Signal Priority Planning and Design Guidelines for implementation in cities throughout the King County service area. The regional cities and the County realize that the traffic impact of implementing TSP to improve transit speed and reliability is a reasonable trade-off for reduced SOV reliance.

4.1.5 Light Rail Transit Signal Priority – Phoenix's Implementation

The Phoenix area will soon be the example for leading-edge practice in TSP for LRT services. Most LRT services use traditional, conditional signal priority or pre-emption. The Central Phoenix/East Valley Light Rail Transit (CP/EV LRT) Project will implement predictive traffic signal priority. Predictive priority is a form of conditional priority, achieved through the use of peer-to-peer communications (meaning that one intersection has the capability to send messages to peer intersections for the purpose of requesting priority, notification of a failed vehicle arrival or confirmation of vehicle detection.) These messages allow the local intersection priority logic to provide a variety of priority strategies, such as to prepare for a vehicle arrival, extend a service phase when needed, and terminate a priority service. The intelligence for making the priority decision is located at the signal controller.

This traffic signal system has the ability to accept advanced detection of approaching light rail vehicles (LRV), with tracking confirmation of LRVs at each upstream intersection. This type of system has been implemented for the Salt Lake City TRAX light rail system and is being implemented for the Houston MetroRAIL system.

The key components of the traffic control system are:

- Traffic signal controller hardware and software;
- LRT vehicle detection system;
- Peer-to-peer communications network (between controllers);

- Central traffic management system communications (existing in Phoenix);
- Central traffic management system (existing in Phoenix); and
- Central controller database management system (existing in Phoenix).

The traffic signal controller hardware is based on the next generation of the NEMA controller platform. This new hardware provides significant computer processor capability; a variety of communications interfaces; and meets all standard NEMA requirements for traffic signal control.

For the CP/EV LRT project, the proposed traffic signal control software is the Siemens GTS ***NextPhase***® intersection management software.

A key component is the LRT vehicle detection system. There are a variety of options. The Salt Lake City TRAX system is based on a combination of inductive loop detectors (located 70' upstream and 20' downstream of each signalized intersection) and radio transceivers (located at the same locations as the inductive loop detectors.) The Houston MetroRAIL system is using a train-to-wayside communications (TWC) system that is part of the LRT trail control system. In both of these systems, the primary functionality is to a provide detector call or detector presence when LRT vehicles are present. The decision on the detection approach for Phoenix will be made over the next 12 months.

Peer-to-peer messaging is achieved through an optical fiber Ethernet network. The detailed design of the communications network depends on potential other uses of the network, including video surveillance and traffic management.

For the purposes of the Phoenix LRT system, communications between the intersection controllers and the central traffic management system can be maintained using the same leased-line multi-drop serial communications currently supported by the Transcore Series 2000 system (using the NTCIP protocol). The purpose of maintaining this interface will be to reduce the requirements for modifications of the existing central traffic management system that is used citywide.

4.2 Transit Traveler Information Systems

Traveler information systems provide transit travelers with fixed information on routes, schedules, and fares, or dynamic information on route delays and real-time arrival estimates.

4.2.1 Pre-Trip Transit/Fixed Information

Most transit agencies provide this fixed information via printed materials and their websites. Valley Metro, the Phoenix area transit agency already has a website (http://www.valleymetro.org) that includes extensive information on existing services such as capital improvement projects of interest to the community. The specific information provided includes:

- Public Transit (bus schedules, maps, fares, how-to-ride, holiday service, bike-on-bus, park-and-ride, school/business programs, dial-a-ride, and light rail project);
- Ride Share (trip reduction program, find-a-ride, carpool, vanpool, bike, telework, compressed work weeks, employer services, and clean air campaign);

- Light Rail (maps, publications, events, meetings, FAQs, project schedule and oversight, DEIS, contracting, press room, other projects, and links); and
- News and Events.

This type of information and web-based format is a standard way for transit agencies to provide pre-trip, fixed information to travelers.

4.2.2 Pre-Trip Scheduling and Trip Planning/Fixed and Dynamic Information

Once a traveler knows what modes of transit are available and how to use the system, they will want to plan their trip. Schedule-based trip planning helps travelers make decisions on the choice of transportation mode, route, and departure time before they begin their trip. Itinerary trip planning uses variables such as minimal travel time and walking distance, fare requirements, least number of transfers, and modal preference (bus, rail, and/or paratransit).

Real-time information can be incorporated with the fixed-route schedule information to provide dynamic information on the location of the transit vehicle en-route and its estimated time of arrival at a selected stop. This information can be made available at transit stations, centers, and major stops, or via web-based platforms such as personal computers and personal digital assistants.

4.2.2.1 Best Practice for Pre-Trip Scheduling and Trip Planning

The best practice involves providing fixed information via a website or through an automated telephone service. Several transit agencies have thorough, easy-to-use websites that walk a user through their transit options and provide route, schedule and fare information. Examples include TriMet (Portland, Oregon) http://www.trimet.org, Pierce Transit (Tacoma, Washington) http://tripplanner.piercetransit.org, King County Metro's (Seattle, Washington) http://transit.metrokc.gov, TranStar Automated Trip Planning System in the Los Angeles Metropolitan Area (http://www.scag.ca.gov/transit) and the Bay Area's (San Francisco, California) http://www.transitinfo.org. The last two systems provide multi-modal and multi-agency integration of bus, rail and intercity train service, which makes it very easy for travelers to get around.

To serve customers without Internet access, the Washington Metropolitan Area Transit Authority (WMATA) (also known as Metro) will be adding an automated telephone trip planning service to its existing website service (http://www.metroopensdoors.com). This automated telephone service is designed to serve the significant portion of Metro's customers who do not have Internet access. With this service, all customers will have access to the same level of service and information. This automated telephone service will operate 24 hours a day, seven days a week and can be accessed by any type of phone including touch-tone, rotary, cellular, or public pay phone. If the caller has difficulty navigating through the automated service, the call will be automatically routed to a customer service agent. Additionally, a caller can request a live agent from the beginning. Metro is considering making a Spanish version of the service available.

4.2.3 On-Board Traveler Information

The dissemination of automated real-time traveler information on board transit vehicles is becoming more popular with transit agencies. These systems provide automated stop announcements, vehicle location information, and emergency and other messaging via audio annunciators and electronic signage.

4.2.3.1 Best Practice for On-Board Traveler Information

In Orlando, Florida, the Lynx Transit Agency has deployed on-board signs that provide automated stop and traveler information in real-time mode. The system is based on a wireless broadcast medium that also delivers daily news, weather, information, entertainment, and advertising to transit customers. Advertising revenue from the system can be used to recover system installation and operating costs, and in some cases provide a positive revenue stream for transit agencies. **Figure 1** shows a typical sign deployed on a bus in Orlando, Florida.

Figure 1 – Typical On-Board Bus Sign, Orlando, Florida

4.2.4 In-Terminal/Wayside Transit Information Systems/Dynamic Information

In-terminal/wayside information systems are devices that provide real-time transit information at bus stations, rail platforms, or other transit transfer facilities, or via other distribution means outside the confines of a transit facility. Presently, real-time transit schedule adherence or arrival/departure information have been distributed via the following systems:

- Annunciators;
- Automated telephone systems;
- Cellular phones with automated data;
- Cellular phones with automated voice;
- Dedicated cable television systems;
- Email or other direct personal computer communications systems;
- Facsimile machines;
- Interactive television;
- Internet websites;
- In-vehicle navigation systems;
- Kiosks;

- Monitor/variable message signs (VMS) (not in vehicles);
- Pagers or personal digital assistants; and
- VMS in vehicles.

Today, the primary devices for providing this information are video monitors and variable message signs. Additionally, audio announcements may supplement the displayed information. Video monitors are used when a large amount of information must be displayed and flexibility in using graphics, fonts and color is needed. Because the character height will be relatively small, video monitors must be mounted in locations and spaces that permit transit users to stand relatively close to the monitor. For example, a video monitor would be well suited for a display at the entrance to a station, to indicate which berth buses serving specific routes are located. A video monitor providing real-time arrival updates, as shown in **Figure 2**, would be less well suited to a central display near a group of bus berths, because transit users might be uncomfortable moving away from the berth and their place in line to get close enough to read the display.

Figure 2 – Video Monitor Providing Real-Time Arrival Updates

VMS are used when a small amount of information must be displayed at a considerable distance from transit users. These signs are appropriate for environments that need a device resistant to vandalism and the environment. The large character heights typically used for longer-distance legibility tend to limit the number of characters that can be displayed, so messages must use scrolling text or be displayed in multiple phrases.

Accessibility requirements for the disabled have provided a reason for transit properties to provide audio and video vehicle arrival information at transit center stations. These systems can supplement on-board audio and video systems to make it easier for the disabled to get around.

4.2.4.1 Best Practices

In King County, Washington, the Metro Transit agency offers a free subscription to Transit Alert!, an e-mail notification system for regular Metro Transit Routes and Metro-operated Sound Transit Routes during weather-related emergencies. Subscribers to the system also can access alert messages via text pagers.

Under the Maricopa County AZTech™ Project, TouchVision kiosks were deployed "to integrate the various traffic management systems of individual cities and implement an integrated regional traveler information system for the multimodal traveler". The intent of this project was to provide various roadway, transit, and aviation information to travelers so that regional mobility and safety would be enhanced. The interactive informational kiosk system is the public medium for providing convenient access to tourism, travel, and community information. More than 25 kiosks were deployed around the greater Phoenix area and along the I-40 Corridor in Northern Arizona. **Figure 3** provides a typical view of the multimodal traveler information kiosk monitor deployed around the Phoenix area.

Figure 3 – Multimodal Traveler Information Kiosk Monitor, Phoenix

Personalized technology such as cellular phones, pagers, and handheld computers is becoming a common way to distribute transit/traffic information to travelers. In all of these delivery methods, the messages can be customized so that a traveler only receives messages relevant to their travel patterns. Travelers usually pay a fee for this tailored information.

In the Seattle area, travelers who use King County Metro's bus services can track the anticipated arrival of their bus on the Internet through a program called MyBus (www.mybus.org). This free system also can be accessed by users of Wireless Application Protocol- (WAP) enabled cell phones. WAP is the technology that makes it possible to link wireless devices (such as mobile phones) to the Internet, by translating Internet information so that it can be displayed on the display screen of a mobile telephone or other portable device. **Figure 4** shows an example of a cell phone screen that displays transit bus route and arrival information through the MyBus system in Seattle.

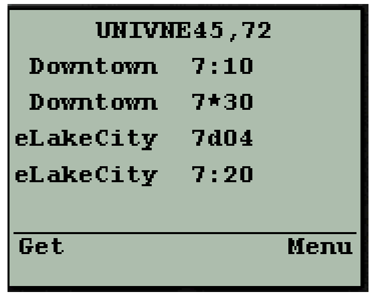

Figure 4 – MyBus Arrival Information Displayed on Cell Phone Screen

The evolution of phone-based traveler information can be found in the development of regional 511 telephone programs. The 511 program is a national effort to deploy regional multimodal traveler information that is accessible to the public via telephone. With this program, all a traveler needs to do is dial 511 to access a menu of up-to-the-minute travel information. Although most 511 applications to date have focused on providing highway information, more systems are incorporating access to transit service and scheduling information. In the Bay Area, the TravInfo® project will soon introduce access to general transit information via the region's 511 system. It also will provide some level of real-time transit vehicle arrival information, similar to the WAP-enabled Seattle area system.

TriMet serves the greater Portland, Oregon area. In fall of 2002, TriMet deployed a real-time tracking system called Transit Tracker for their buses. Transit Tracker uses GPS to track how far buses are from bus stops. Every bus is equipped with a transmitter that allows the vehicle to be constantly tracked within an accuracy of 30 feet. The real-time information is displayed on electronic displays in busy bus shelters and online at http://www.trimet.org. The website provides minute-by-minute countdowns of bus arrivals at about 8,000 stops and is updated every 50 seconds.

If the system cannot make an accurate prediction (e.g., the vehicle is too far away or its transmitter is not working), the scheduled arrival time is displayed instead. If there are several buses for a single stop, Transit Tracker displays information for all of them. In the event of an emergency, Transit Tracker also can provide important information and instructions to riders.

Currently, TriMet has installed the electronic displays at 10 bus stops and 11 MAX (light rail) stations. By the end of 2003, TriMet will have installed over 60 displays, with priority given to high-ridership stops and transfer locations.

The electronic displays at the MAX stations currently show scheduled arrival times only. TriMet is in the process of upgrading the system that tracks MAX trains, so that Transit Tracker will display MAX's actual arrival times.

In conjunction with the Transit Tracker displays, TriMet's website has been redesigned so that trip planner, route finder, Transit Tracker and fare information is easily accessible.

The Chicago Transit Authority (CTA) will soon be installing VMS at both O'Hare and Midway airports to show real-time transit and traffic information. The signs will be placed in the baggage claim and passenger concourses, and will display a countdown of minutes until the next departing train, travel times to downtown via the CTA's orange and blue line trains, and travel times on the Kennedy or Stevenson expressways. The signs also will display fare information, CTA service disruption or delay messages, and airport emergency information. They will be connected to the CTA's automatic train dispatching and monitoring system and the Illinois DOT's highway monitoring system to collect real-time information.

NextBus is a real-time transit information service (not system) used by a number of transit agencies in California, Virginia, Massachusetts, Pennsylvania, Delaware, Maryland, Colorado, and Oklahoma. Although NextBus is not the only real-time transit information service available, it represents a best practice of supplying the information via another method.

Travelers can go to the transit agencies' website or go to the NextBus website (http://www.nextbus.com) to receive real-time information on their routes. This arrival time information is made available on the World Wide Web and to wireless devices including signs at bus stops and businesses, Internet-capable phones, and personal digital assistants.

NextBus uses GPS satellites and advanced computer modeling to track vehicles on their routes. The actual position of buses, intended stops, and typical traffic patterns are combined to estimate the vehicle's arrival time.

In the Seattle area, King County Metro bus users can get similar NextBus functionality through its BusView product. BusView (www.busview.org) provides real-time bus location information based on the County's signpost automatic vehicle location system. Signpost-based AVL systems are generally considered old technology, as many transit properties are moving towards GPS-based AVL systems; however, King County has a robust network of signpost locations and has taken advantage of it by generally deploying a cost-effective AVL solution that meets its needs. King County is planning on upgrading to a GPS-based system as it slowly upgrades it large communication network.

4.2.5 Institutional Issues

The cooperation and participation of many stakeholders who directly or indirectly impact the deployment of transit traveler information systems will be needed in order to make information useful to travelers. Stakeholders would include:

- Transit system service users, including commuters, the aged, the disabled and others;
- Schedulers, operators, analysts, ITS staff and project managers for each transit agency;
- Traffic engineers and operations staff from each city;
- Technology vendors;
- Information technology staff or consultants; and
- Transit agency policy officials.

Assuming that vehicles are equipped to transmit location information (this is a huge assumption), there must be agreement on the type of information to be displayed. Agencies need to determine whether there are guidelines already in place to disseminate travel information, and whether these guidelines specify standards for the user interface. Are there ADA requirements that need to be addressed? Are there public safety issues that need to be addressed?

It must then be decided which agency will provide the information, how will it be shared, whether it will be "read-only", how will it be transmitted, what to do if there is conflicting information, etc. This step alone may prove to be the most difficult to overcome. It must then be decided how to display and disseminate the information. The finer details on how often to update the information must be decided. Finally, the information must be integrated with the technology to be displayed to travelers.

Although the challenges listed above are not exhaustive, they do provide a framework for the types of issues that must be overcome. It is important to remember that other agencies have been able to resolve these types of issues and will be able to provide guidance as the process moves forward.

4.3 Advanced Traveler Information Systems

4.3.1 Recommendations for the Traveler Information Systems in the MAG Region (2)

Most cities address issues of ATIS in a unique manner; planning and implementation are clearly influenced by population, geography, and existing infrastructure. As one of the fastest-growing metropolitan regions in the country, agencies in the MAG Region have an especially important responsibility to study a variety of models and implementation plans so as to best serve the ITS needs of the community.

The following 11 items were recommended (2) to serve as guidelines for the expansion of Traveler Information Systems in the MAG Region.

1. Concentrate on data availability and quality

Collecting and providing accurate, up-to-date and thorough information is the most essential issue facing the architects of any ATIS product. Work to collect the most information from as many sources as possible. Data from arterials is just as important as data from limited access highways; in the case of the MAG Region, even more important, and the travel information system should be poised to provide the best arterial data infrastructure in the nation. Include a truly multi-modal product that offers information on transit, paratransit, and weather conditions in addition to roadway information.

2. Provide a basic service in availability and quality

ITS industry standard suggests a comprehensive ATIS product be available in the form of an interactive web site and an interactive voice response (IVR) system. ATIS information in the region should be accessible to anyone with a phone, and anyone with Internet access. Basic quality standards must be adhered to so that the product disseminated is consistent no matter what the method of dissemination.

3. Create a long-term coalition of ITS stakeholders

Representatives from local agencies such as transportation, emergency services, air quality, and media outlets should be included in an active coalition, and should attend regular meetings in order to share their needs and concerns, and participate in plans of action to meet those needs.

4. Tailor the product to meet the needs of the consumer

Identify the customer, and find out his needs and desires. Gather focus groups of travelers in the Valley to find out what they want from information services. Allow for updated gathering of this data, so trends can be tracked over time, and information shared with potential partners. Users need to know first and foremost: how congested is the traffic ahead? How long will it take me to get from point A to point B? Incident data is important, but it is the effect of incidents that make traffic news. Concentrate on giving the user congestion or impact-related information first, followed by secondary incident details. Automatic systems should be constructed so that impact data is given first.

5. Create an environment of advanced services to prosper when ready

While it's well known that the paying customer for traveler information has not yet been adequately identified, work in spite of the unknown to create a platform for advanced, innovative services to be available when the market is finally defined. Simplify the approach to access data, so that the greatest number of customers can participate in any product.

6. Use a combination of national models

There is no one perfect model from which to build. Instead, it is beneficial to take elements from each model that works and build a customized solution for Maricopa County. Large differences in population, landscape, and infrastructure dictate that we must meld the best of different models into a solution for the MAG Region. The travel information system must build upon existing ITS institutional relationships and infrastructure. Build an ATIS service that is integrated, regional, and multi-modal.

7. Rely first and foremost on public funds

The accurate and timely dissemination of ATIS data is the responsibility of public agencies, but an opportunity for private firms. Public agencies have a responsibility to the customer with regard to ATIS dissemination. The more traveler information disseminated, the better for the traveling public, the infrastructure and the economy. As ATIS benefits the public in terms of time, money and lives saved, the responsibility lies first in public funding, with an outreach to private firms an important, but secondary, pursuit.

8. Concentrate on arterial coverage

The MAG Region covers a great deal of arterial road miles in addition to the limited access freeways miles; those streets need the benefit of ATIS equipment and service just as much as freeways.

9. Fund an aggressive and sustained marketing campaign

Marketing and promotion is a greatly under-appreciated and underused tool in the dissemination of ATIS products. In each and every survey referenced in this report, participants note that there does not exist in the community an awareness of the services being offered. Studies have found that "outreach using other media could significantly increase awareness and use of the web site among a broader base of…residents". Several members of the Seattle focus group had only just stumbled upon the WSDOT or Smart Trek site; much more use could be generated with some marketing throughout the community. In an evaluation of the SmarTraveler product in Boston, "only a third of these potential users reported that they had heard of SmarTraveler and believed they knew what it was".

Marketing is an absolutely critical factor in determining use rates for ATIS. We have to appreciate the importance of diverting enough time and funds to market the product and convince the community to use it. Advertising and promotion is clearly the biggest factor in determining if the populace become users, and consequently beneficiaries, of the services. It's important to identify the potential user as not just the Internet-savvy but also the regular users of the IVR systems. There is an important truth: users of ATIS systems, even sporadic ones, are across the board likely to rate the service highly; in other words, those who can find the service use it and like it.

10. Focus on the benefits of a public/private partnership

It is rare that an ATIS service is exclusively private, or exclusively public. A commitment to a collaborative partnership between interests allows new ideas and perspectives to emerge. When both are involved in an open-architecture format, it is then possible to leverage the contribution of both types of partners so as to create the most useful product. Bringing together many diverse private companies who complement each other results in a broad and thorough output. For example, the TravInfo project in San Francisco lists no less than 45 private firms whom telnet into the system to receive outgoing data. Each company is then free to add value to, market, and distribute ATIS data to the commuting public. To that end, it is imperative to interview public stakeholders, as well as representatives from private companies regarding the product. Develop a comprehensive outreach program for public and private parties to participate in effective deployment of the program. Hire a marketing firm to survey the community to find out what commuters want from an ATIS product.

11. Use advances in technology

Keep on staff, or contract out, technical project managers who can advise stakeholders on advances in communications and other related industries. There are advances that require only minimal financial input. In the same vein, rely on the services of a web designer or design company to regularly update the look and feel of traffic web sites. The aesthetics of a web site are crucial to the user experience, and by extension the usefulness of the product. Of the cities we studied, WSDOT in Seattle and CommuterLink in Salt Lake City stand out as exceptional sites. Something as simple as how good a site looks is more important than it might seem initially.

4.3.2 Action List/Next Steps (2)

- Hold a series of focus groups throughout Maricopa County, and implement a customer satisfaction survey on the AZTech™ web site. Identify the active customer and services currently offered which are the most widely used. Identify further the services Valley residents would like to see made available;
- Improve the web site. Streamline the graphical interface, and bring the graphics and services up to standard;
- Release a Request for Proposals to create a state of the art IVR system; and
- Identify possible partners – invite media outlets to discuss participating in an in-kind bartering agreement where AZTech™ gets media exposure in exchange for the use of traffic data.

5. WORKS CITED

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